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Vincent Breteau, Fabien Leurent

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Vincent Breteau†[1,2] and Fabien Leurent[1]

[1]Université Paris-Est - École des Ponts ParisTech - LVMT
[2]French Ministry of Environment, Transportation and Housing

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Abstract

Our objective in this paper is twofold: first, we want to give a theoretical founding to empirical findings of several works that emphasize the fact that while distance traveled increases with household location distance from the city center, transportation time tends to decrease, thus offering a strong incentive to sprawl. Second, we want to analyze the impact of job dispersal on city size, overall distance traveled and transportation cost, along with other urban variables, and spatial equity. We therefore develop an extended monocentric model of city taking into account employment dispersal and varying unit commuting costs. Using this model, we show that under specific conditions including employment dispersal and high marginal transportation cost around city center, the distance traveled by households from home to workplace increases with their distance from the city center, while private transportation costs they endure decrease. Then, based on a surplus analysis, we show that city size moderately increases with the level of employment dispersal, while overall home-to-work distance traveled decreases, suggesting that job decentralization might entail savings in social costs of transportation. However, our findings show that such dispersal could entail spatial inequity: the households living near the city center could suffer a welfare loss.

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†Corresponding author (vincent.breteau@enpc.fr)

1 Introduction

Urban sprawl remains one of the most acute problems in urban areas and is one of the main stakes of urban economics today. Sprawl induces excessive space consumption and, concerning more specifically transportation, has consequences on energy consumption[1] and congestion. It is well acknowledged in a vast literature, both theoretical and empirical, that urban sprawl and transportation are deeply linked (e.g. Fujita, 1989; Kahn, 2007; Glaeser and Kahn, 2008), even though their exact relationship in a given city remains doubtful. Melia et al. (2011) show indeed that urban intensification does not necessarily entail welfare improvement. It seems that beyond density, urban form is a largely determining factor of transportation use (Aguiléra and Mignot, 2007; Charron, 2007). As part of the equation, job decentralization is also often considered as a driver or a byproduct (Bruegman, 2005; Buchfield et al., 2006) of urban sprawl. More generally speaking, whereas the compact city is often seen as the green city, several works suggest that the cost of compacity is not insignificant (see for instance Castel, 2005, concerning France).

As already mentioned, theoretical studies have already tackled the link between urban sprawl and transportation. The seminal work of Wheaton (1974) has emphasized, in a monocentric setting, the role of transportation cost decrease or income increase in urban sprawl. However, many other variables may play a role: preference for green environment, congestion, housing price, urban blight, etc. Among these, job localization, and more precisely job decentralization, plays an ambiguous role. Some authors consider it as one of the drivers of urban sprawl, pushing households at the urban periphery (e.g. Buchfield et al., 2006). But other authors emphasized the fact that jobs may *follow* the sprawl of households instead of drive it (e.g. Bruegman, 2005). Yet, few theoretical work have focused on this variable. The vast majority of theoretical urban models based on the standard monocentric model (Alonso, 1964) assume indeed that the CBD size is zero or that transportation is costless in the CBD, which is actually equivalent. This is a quite reductive assumption, as job dispersion has been empirically shown (e.g. Giuliano and Small, 1993; McMillen and McDonald, 1998; Glaeser and Kahn, 2001). Some authors such as White (1976, 1988, 1999) have explicitly introduced the locations of jobs in a monocentric setting. These works focused however on a long-term equilibrium where wages depend on the locations of the firms. While empirical works have shown the existence of a wage gradient (e.g. Timothy and Wheaton, 2001), Mills and Hamilton (1994) have

[1] And hence on GES emissions and local pollution.

emphasized that the wage adjustment process entails the fact that the rent function form is unaffected by the localization of jobs, or differently put that job localization has no effect on urban sprawl, which is a doubtful conclusion.

In Breteau and Leurent (2010), henceforth BL10, we developed an extended monocentric model in which jobs are distributed exogenously in an employment area where the transportation cost is nonzero. In addition, we also assume households to be homogeneous in terms of utility and gross income and each household to have a fixed place of employment that influences its residential location. Our model is therefore one of medium-term equilibrium, where households are the only participants in the housing market and do not compete with firms. We have proved in BL10 the existence and uniqueness of the equilibrium, and derived the main comparative statics of the model.

In this paper, we use the model to provide answers to the following questions: does the decentralization of jobs constitute a potential driver of urban sprawl? Can job decentralization entail a transport-sober urban development? We thus give a founding to empirical findings showing that while distance traveled increases with household location distance from the city center, transportation time tends to decrease, offering a strong incentive to sprawl (Fouchier, 1997; Genre-Grandpierre, 2007). We also show that whereas job decentralization has a moderate negative impact on city size, the impact is positive and strong on overall distance traveled and transportation cost.

The paper is organized as follows: the next section describes the main assumptions of the model and recalls the main results of BL10. Section 3 presents our results concerning the first question addressed and section 4 discusses our results concerning the second question. Section 5 concludes.

2 The model and its assumptions

2.1 Firms and workplaces

We consider a city in which firms, and therefore jobs, are distributed around a centre in a disk of radius ρ_f: we call it the employment area, composed of a CBD of radius r_0 exclusively reserved to jobs, and a mixed area ranging from r_0 to ρ_f. Jobs are assumed to be distributed following a radial density $f(\rho)$ that is non-zero on an interval of $[0, \rho_f]$, yielding a cumulative distribution function $F(\rho) = \int_0^\rho f(r)dr$. The function F is therefore strictly increasing. The number of jobs is fixed at N, therefore $F(\rho_f) = N$.

2.2 Households

As regards households, we assume: (H1) that the households are located in a ring around the CBD. (H2) That the households are homogeneous in their preferences. (H3) That each household has only one working member employed by a firm in the employment area. (H4) That each household receives an income Y from this job, independent of residential and job location[2]. Finally, (H5) each household has a fixed workplace. The choice of a residential location in r by a household whose workplace is ρ, leaves them a net income of $I = Y - T(\rho, r)$, where T is the transportation cost. Households utility U depends on the size of its dwelling, s, and on the quantity z of a composite consumption good treated as numéraire. The function U is assumed to be increasing and continually differentiable into each of its variables. In general terms, each household is deemed to be a rational decision maker, which seeks to maximize its utility subject to its budget constraint.

2.3 Spatial structure of the residential area

We are interested here in the land market within the residential zone only: the unit price of land in r, or land rent, is denoted $R(r)$. The opportunity cost of land, corresponding to an alternative use (e.g. agricultural), is denoted R_A. The economic program of the household working at ρ is expressed as follows:

$$\max_{r,z,s} U(z, s) \text{ s.t. } z + R(r)s \leq Y - T(\rho, r). \tag{1}$$

The density of the households in r is denoted $h(r)$. This is, with the land rent, the main endogenous variable in our model. For reasons of symmetry with the distribution of jobs, we introduce the cumulative household distribution function, $H(r) = \int_{r_0}^{r} h(r)dr$. Conservation of the relative orders of jobs and households[3] allows us to define a function $\rho \mapsto r_\omega(\rho)$ yielding, for a given workplace, the corresponding equilibrium location of the household, that is such that: $H(r_\omega(\rho)) = F(\rho)$. Regarding the transportation cost, it

[2] i.e. employers are indifferent to the residential location of their employees: this is a reductive hypothesis for the statistical distribution of incomes, since empirical research has shown the existence of an income gradient within cities (Eberts, 1981; McMillen and Singell, 1992; Timothy and Wheaton, 2001). Nevertheless, Glaeser and Kahn (2001) have shown that employment deconcentration tends to generate homogenization of incomes.

[3] This property is shown in BL10 with a proof based on the Rule 2.3 in Fujita (1989, p.28), a smaller ρ entailing a steeper bid rent for the household, and thus a residential location closer to the CBD.

is assumed that $T(\rho, r)$ is a decreasing function in ρ and increasing in r. Finally, the amount of space available at r is denoted $L(r)$.

2.4 Equilibrium characterizing system

On the demand side, we define the indirect utility function of a household as follows:

$$V(R, I_\rho) = \max_{s,z} \left\{ U(s,z) \middle| z + Rs \leq I_\rho \right\}. \tag{2}$$

We then note $W(r, \rho) = V(R(r), Y - T(\rho, r))$, so that the economic program of the household given by (1) may be rewritten:

$$\max_{r} \ W(r, \rho). \tag{3}$$

On the supply side, as no land is left vacant and as land is allocated to the highest bider, we have, for all $r \leq r_f$:

$$h(r)s(r) = L(r), \tag{4}$$

$$R(r) \geq R_A. \tag{5}$$

Condition (3) yields:

$$\partial W(r, \rho)/\partial r = 0 \quad \text{at point } \rho = \rho_\omega(r), \tag{6}$$

that is:

$$R'(r)\frac{\partial V}{\partial R} = \frac{\partial T(\rho_\omega(r), r)}{\partial r}\frac{\partial V}{\partial I}. \tag{7}$$

Using Roy's identity, we obtain the Muth condition:

$$R'(r) = -\frac{\partial T(\rho_\omega(r), r)}{\partial r}/\hat{s}(R, I_{\rho,r}), \tag{8}$$

with $I_{\rho,r} = Y - T(\rho_\omega(r), r)$, the net revenue, $\rho_\omega(r) = F^{-1} \circ H(r)$ the reciprocal of r_ω and $\hat{s}$ the Marshallian demand for space.

Condition (4) then yields:

$$H'(r) = L(r)/\hat{s}(R, I_{\rho,r}), \tag{9}$$

for the equilibrium lot size $s(r)$ corresponds to $\hat{s}(R, I_{\rho,r})$, the bid-max lot size.

The urban equilibrium is thus characterized by the following differential system:

$$\left\{ \begin{array}{lcl} R'(r) & = & -\frac{\partial T(\rho_\omega(r), r)}{\partial r}/\hat{s}(R, I_{\rho,r}) \\ H'(r) & = & L(r)/\hat{s}(R, I_{\rho,r}) \end{array} \right. . \tag{10}$$

Using this system we were able to show existence and uniqueness of the equilibrium, defining for that purpose a terminal rent function[4], similar to the boundary rent function in Fujita (1989): see BL10 for details.

2.5 A specific model

In order to achieve analytical resolution when it is needed, we use specific forms for the exogenous variables of the model. Concerning the utility function, the literature has extensively considered the Cobb-Doublas form (or log-linear form, see Fujita, 1989):

$$U(z, s) = U_0 z^\alpha s^\beta, \tag{11}$$

with $\alpha, \beta > 0$ and $\alpha + \beta = 1$.

We assume that residential land capacity and job distribution are uniform, that is $L(r) = \lambda > 0$ for all $r > r_0$, $f(\rho) = N/\rho_f$ for $\rho \in [0, \rho_f]$ and $f(\rho) = 0$ for $\rho > \rho_f$, with N the number of households in the city. Finally, we assume that the generalized cost of transport may be written as follows:

$$T(\rho, r) = a_0 + ar - a'\rho, \tag{12}$$

where a' and a are the respective unit transport cost in the employment area and outside, and $a_0 = \bar{a_0} + (a' - a)\rho_f$ with $\bar{a_0}$ the fixed cost of transport, reflecting, among others, car ownership and parking costs.

In this specific framework, the system (10) becomes:

$$\left\{ \begin{array}{lcl} R'(r) & = & -\frac{a}{\lambda} H'(r) \\ H'(r) & = & \frac{1}{\beta} \frac{\lambda R(r)}{Y - a_0 - ar + a'\rho_\omega(r)} \end{array} \right. , \tag{13}$$

which yields, after resolution, a closed form for $r_\omega(\rho)$:

$$\forall \rho \in [0, \rho_f], \quad r_\omega(\rho) = A + B\left(1 - \frac{\rho}{\tilde{\rho}}\right) - C\left(1 - \frac{\rho}{\tilde{\rho}}\right)^\beta, \tag{14}$$

[4] This function $\hat{R}$ gives, for a given value R_0 of the rent at the beginning of the residential area, the value of the rent at the distance within which all households are located. The urban equilibrium is then characterized by R_0^* such that $\hat{R}(R_0^*) = R_A$.

where:

$$
\begin{aligned}
A &= \frac{Y - a_0}{a} + \rho_f \frac{a'}{a} \left(\frac{\lambda R_A}{aN} + 1 \right), \\
B &= \frac{\beta}{\alpha} \rho_f \frac{a'}{a} \left(\frac{\lambda R_A}{aN} + 1 \right), \\
C &= A + B - r_0, \\
\text{and } \tilde{\rho} &= \rho_f \left(\frac{\lambda R_A}{aN} + 1 \right).
\end{aligned}
$$

3 Decentralization of jobs and congestion as drivers of urban sprawl

As already mentioned in the introduction section, some authors (especially Fouchier, 1997) have emphasized the fact that distance traveled by households and the time they spend traveling do not follow the same evolution with distance from the CBD. While traveled distance generally increases with distance to the city center, which constitutes a major source of adverse effects of urban sprawl, the time spent in transport tends to decrease, thus creating a strong incentive to sprawl.

The standard monocentric model is unable to account for this disjunction between distance traveled and time spent in transport. Within the framework of our model however, it is possible to analyze this phenomenon. For this, we study the traveled distance for home-to-work trips, denoted $\hat{D}(r) = r - \rho_\omega(r)$ and the transport cost[5], denoted $\hat{T}(r) = T(\rho_\omega(r), r)$. The respective evolutions of $\hat{D}$ and $\hat{T}$ with r are given by:

$$
\frac{d\hat{D}(r)}{dr} = 1 - \rho'_\omega(r), \tag{15}
$$

$$
\begin{aligned}
\frac{d\hat{T}(r)}{dr} &= \rho'_\omega(r) \frac{\partial}{\partial \rho} T(\rho_\omega(r), r) + \frac{\partial}{\partial r} T(\rho_\omega(r), r) \\
&= \frac{\partial T}{\partial \rho} \left[\rho'_\omega(r) + \frac{\partial T / \partial r}{\partial T / \partial \rho} \right].
\end{aligned} \tag{16}
$$

We can assume that $\rho'_\omega < 1$ for all r, which reflects observation that households are more dispersed than jobs, even only slightly (Wheaton, 2004). That gives $\hat{D}'(r) > 0$. We also have $\partial T / \partial \rho \leq 0$ and $\partial T / \partial r \geq 0$. The sign of $\hat{T}'(r)$ depends on value of $\frac{\partial T / \partial r}{\partial T / \partial \rho}$.

[5]This cost may be seen as a generalized transport cost, in which the time cost constitutes the major part.

We define two typical situations: the first one, called *congested*, is defined by $|\partial T/\partial \rho| \geq \partial T/\partial r$, meaning that the unit transport cost is higher in the center of the city than at the periphery. Thus, in this situation, $\frac{\partial T/\partial r}{\partial T/\partial \rho} \geq -1$. The second typical situation, called *massified*, is defined by $|\partial T/\partial \rho| \leq \partial T/\partial r$, meaning that the transportation system is very efficient at the center of the city allowing the unit transport cost to be lower there than at the periphery. Thus, in this situation, $\frac{\partial T/\partial r}{\partial T/\partial \rho} \leq -1$.

Each of these typical situations for the transportation system may then lead to a typical configuration for the city. The *massified* situation leads to a configuration we called *quasi-monocentric* for distance traveled and time spent both increase with distance from the city center, as predicted by the standard monocentric model. On the contrary, the *congested* situation leads to a configuration we called *deconcentrated*, in which distance traveled increases with distance from the city center, while time spent decreases.

With the specific model described in subsection 2.5, the sufficient condition for the *quasi-monocentric* configuration is:

$$\rho_f \left(\frac{\lambda R_A}{aN} + 1 \right) \leq \beta \big(Y - a_0 - a r_0 \big) \min \left[\frac{1}{a'}, \frac{1}{a} \right], \tag{17}$$

which may be obtained for a not too high, $a' \lesssim a$ and a small ρ_f.

As to the *deconcentrated* configuration, for a not too high to ensure $\left(\frac{\lambda R_A}{\lambda R_A + aN} \right)^{\alpha} - \beta > 0$, the sufficient condition is:

$$\alpha \beta \frac{Y - a_0 - a r_0}{a'} \left[\left(\frac{\lambda R_A}{\lambda R_A + aN} \right)^{\alpha} - \beta \right]^{-1} \leq \rho_f \left(\frac{\lambda R_A}{aN} + 1 \right) \leq \beta \frac{Y - a_0 - a r_0}{a}, \tag{18}$$

which may be obtained for $a' \gg a$ and a quite large ρ_f.

Fig. 1 illustrates this *deconcentrated* configuration for the following values of the parameters: $a = 0.5$ *euro/km*, $a' = 3$ *euros/km* and $\rho_f = 5$ *km*.

This shows that, when taking into account a spatial distribution of jobs, congestion in the center of the city may lead to a decrease in time spent in transport with distance from the city center, while distance traveled increases. This creates for households a potential incentive to sprawl, as they may thus benefit from a smaller transport cost. In the same time, the distance they travel increases, with the negative effects this may have on energy consumption, GES and local pollutant emissions. In terms of transport policy, this result suggests that policies consisting of capacity reduction in central areas without an efficient alternative transportation mode (rapid transit) potentially lead to more sprawl.

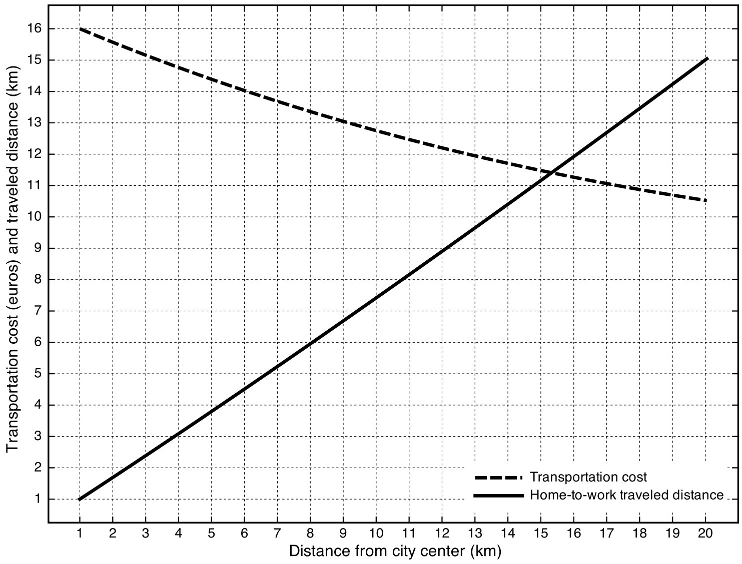

Figure 1: Transportation cost and home-to-work traveled distance in a *deconcentrated* city

4 Transport-sober urban development

We now focus on the second question we raised in the introduction of this paper: is decentralization of jobs able to induce a transport-sober urban development? To answer this question, we compare two contrasted scenarios with a reference one. These *scenarii* differ by the level of decentralization of jobs: low, medium (for the reference) and high, the total number of jobs being fixed. Using our notations, it means that $\rho_{f1} < \rho_{f0} < \rho_{f2}$, where index 0 stands for the reference scenario, index 1 for the low decentralization scenario, and index 2 for the high decentralization one.

We simultaneously consider two situations concerning the transport cost in the employment area: uncongested, meaning for instance that the use of several modes of transport allows for a low level of congestion in the city center, and congested, if car is the main mode of transport.

4.1 Surplus-neutral scenarios

As the location of jobs has an impact on the utility level of households, we want a means to compare comparable scenarios. When all households achieve the same utility level at equilibrium, as in De Palma et al. (2008) for instance, it may be obtained by adjusting income by a population tax, following the Herbert-Stevens model (Fujita, 1989). In our case, however, all households do not achieve the same utility level. We thus compare scenarios for which the overall surplus of switching from one situation to the other is zero.

We note $\sigma(n)$ the surplus that a household indexed n may benefit when switching from a scenario i to a scenario j:

$$\sigma(n) = Y_j - \Big(Y_i + CVI(n)\Big), \tag{19}$$

where CVI is the compensating variation of income. With a Cobb-Douglas utility function, CVI may be written as:

$$CVI(n) = T\Big(\rho_j(n), r_j(n)\Big) - Y_i + \Big(Y_j - T\Big(\rho_j(n), r_j(n)\Big)\Big)\frac{V_i}{V_j}, \tag{20}$$

where V_i and V_j are the utility levels of the household in both scenarios. Injecting (20) in (19), we have the expression of surplus for household n:

$$\sigma(n) = \Big(Y_j - T(\rho_j(n), r_j(n))\Big)\frac{V_j - V_i}{V_j}. \tag{21}$$

Using the expression of the indirect utility function, and replacing $T(\rho, r)$ by its expression, we obtain:

$$\begin{aligned}\sigma(n) = {} & (Y_j - Y_i) + \\ & (\rho_{fj} - \rho_{fi})\frac{a'}{\alpha}\frac{\lambda R_A + a(N-n)}{aN}\left[\left(\frac{\lambda R_A + aN}{\lambda R_A + a(N-n)}\right)^{\alpha} - 1\right].\end{aligned} \tag{22}$$

For the whole city population, we have:

$$\begin{aligned}\mathbf{S_{i\to j}} &= \int_0^N \sigma(n)dn \\ &= N(Y_j - Y_i) + \\ &\quad (\rho_{fj} - \rho_{fi})\frac{a'}{\alpha}\int_0^N \frac{\lambda R_A + a(N-n)}{aN}\left[\left(\frac{\lambda R_A + aN}{\lambda R_A + a(N-n)}\right)^{\alpha} - 1\right] dn.\end{aligned} \tag{23}$$

The explicit calculation of the integral yields:

$$\int_0^N \frac{\lambda R_A + a(N-n)}{aN}\left[\left(\frac{\lambda R_A + aN}{\lambda R_A + a(N-n)}\right)^{\alpha} - 1\right] dn = \frac{\eta(\alpha) - \eta(0)}{aN} \geq 0, \tag{24}$$

where function η is defined by:

$$\epsilon \mapsto \eta(\epsilon) = -\frac{(\lambda R_A + aN)^{\epsilon}}{a(2-\epsilon)}\Big[(\lambda R_A + aN)^{2-\epsilon} - (\lambda R_A)^{2-\epsilon}\Big]. \tag{25}$$

Finally, as we want to compare the scenarios on the same basis, we choose the income levels Y_1 and Y_2 for scenarios 1 and 2 so that $\mathbf{S_{0\to 1,2}} = 0$:

$$Y_{1,2} = Y_0 + \frac{\rho_{f0} - \rho_{f1,2}}{N}\frac{a}{\alpha}\frac{\eta(\alpha) - \eta(0)}{aN} \tag{26}$$

4.2 Parameters choice

In order to compute numerical simulations, we have to choose the values for the parameters of the model. Hence, we consider a city with $1,700,000$ households, and a CBD of radius 1 km. This corresponds roughly to the Greater Paris region characteristics. The Cobb-Douglas utility function parameters are set to $\alpha = 0.72$ and $\beta = 0.28$, meaning that about one-third of the income net of transportation cost is devoted to housing[6]. The land capacity is set to $\lambda = 6$ km, the agricultural rent to 8 euros/m^2/month, and the gross income in the reference scenario to $Y_0 = 2,500$ euros/month.

Concerning the transportation cost, the unit cost is set to $a = 1$ euro/km in the purely residential area, to $a' = 1$ euro/km for the uncongested situation and to $a' = 2$ euros/km in the congested situation, in the employment area. The 'fixed' part of the transportation cost, $a_0 = \bar{a_0} + \rho_f(a' - a)$, is assumed independent of ρ_f, through an adjustment of $\bar{a_0}$. As $\bar{a_0}$ mainly accounts for parking costs (monetary and search cost) or, in the uncongested case, for park-and-ride cost or fixed transit cost, we simply assume that, in the congested case, these costs decrease with the decentralization level, while in the uncongested case, they keep their reference values.

The radius of the employment area is set to $\rho_{f0} = 5$ km for the reference scenario, $\rho_{f1} = 2$ km for the low decentralization scenario and $\rho_{f2} = 8$ km for the high decentralization scenario. The gross income established by equation (26) and the values of $\bar{a_0}$ are given in Tab. 1.

Congested	Scenario	Income (eu/m)	$\bar{a_0}$ (eu/trip)
	Reference	$2,500$	
No	Low decent.	$2,526.5$	3
	High decent.	$2,473.5$	
	Reference	$2,500$	3
Yes	Low decent.	$2,553$	6
	High decent.	$2,447$	0

Table 1: Gross income and 'fixed fixed' part of transportation cost for the different situations and scenarios.

[6]And about one-quarter of the gross income, as the transport budget is 14 % of the gross income in France (Arthaut, 2005). This figure of roughly 25 % is in line with Omalek (2003).

4.3 Results from numerical simulations

The main results of the numerical simulations are summarized in Tab. 2, in which r_f is the city radius, $\overline{D}$ the average distance traveled by households for home-to-work trips, $\overline{T}$ the average transportation cost they face.

Congested	Scenario	r_f (km)	$\overline{D}$ (km/trip)	$\overline{T}$ (eu/trip)
	Reference	18.24	6.51	9.51
No	Low decent.	18.19	8.02	11.02
	High decent.	18.28	4.99	7.99
	Reference	17.92	6.30	11.80
Yes	Low decent.	17.83	7.83	14.83
	High decent.	18.02	4.77	8.77

Table 2: Main results of the numerical simulations.

These results suggest that employment decentralization has a quite small impact on the city radius: the elasticity of city radius with respect to employment area radius is 0.01 when the city center is congested. However, in the same time, the distance traveled for home-to-work trips and the transportation cost strongly decrease: the elasticities are respectively -0.4 and -0.43. To put it another way, even though the model only deals with home-to-work trips, the findings suggest that compacification (Melia et al. 2011 use the word intensification) may not have an important impact in terms of land use but an important negative impact in terms of distance traveled, and thus energy consumption and pollution, especially when the level of congestion is high.

Concerning the land rent and the lot sizes, we find a very small impact of the level of dencentralization on land rent, mainly because of the income adjustment, which allows households to keep the level of their bid almost unchanged. The lot size (and symmetrically the density) is impacted differently in the center and at the periphery, as illustrated by Fig. 2.

4.4 Spatial equity

In our model, the location of jobs has an impact on the distribution of utility levels through space. The workplace constitutes indeed an indirect income. To measure and compare the utility levels in monetary terms, we use the equivalent variation of income, or rather the equivalent income: the income that a reference household, for instance the household working at the very center of the CBD, *i.e.* in $\rho = 0$ and living in r_0, should receive in order to

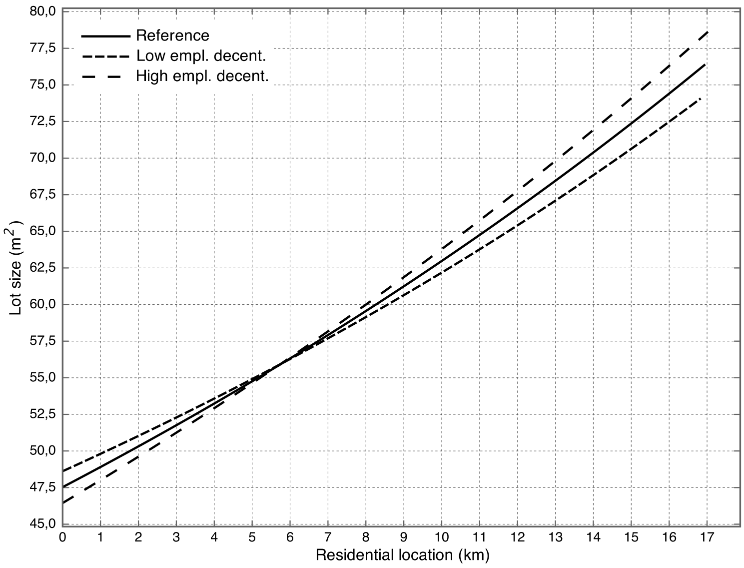

Figure 2: Lot size in the three scenarios.

achieve the utility level u_ρ of another household. This equivalent income is defined as:

$$\tilde{Y}_{\rho=0}(\rho) = T_\omega(\rho = 0) + E(R_{\rho=0}, u_\rho), \tag{27}$$

where $E(R, u)$ is the expenditure function, giving the net income that allows a household facing a land rent of R to achieve utility level u.

With our Cobb-Douglas utility function, this expression becomes:

$$\tilde{Y}_{\rho=0}(\rho) = Y + \frac{a'}{\alpha}\rho_f \frac{\lambda R_A + aN}{aN}\left[1 - \left(\frac{\lambda R_A + aN\left(1 - \frac{\rho}{\rho_f}\right)}{\lambda R_A + aN}\right)^{\alpha}\right]. \tag{28}$$

Fig. 3 illustrates the result for the three scenarios. With a high level of employment decentralization, the equivalent income curves is steeper, meaning that the level of inequality is higher than with a low level of decentralization. Moreover, in the high decentralization scenario, households working close to the city center achieve a lower utility level than in the reference scenario, while the diagnostic is reverse for households working far from the center. This result suggests that the households working in the CBD and the the households working at the periphery of the employment area would probably not support the same policies toward jobs localization.

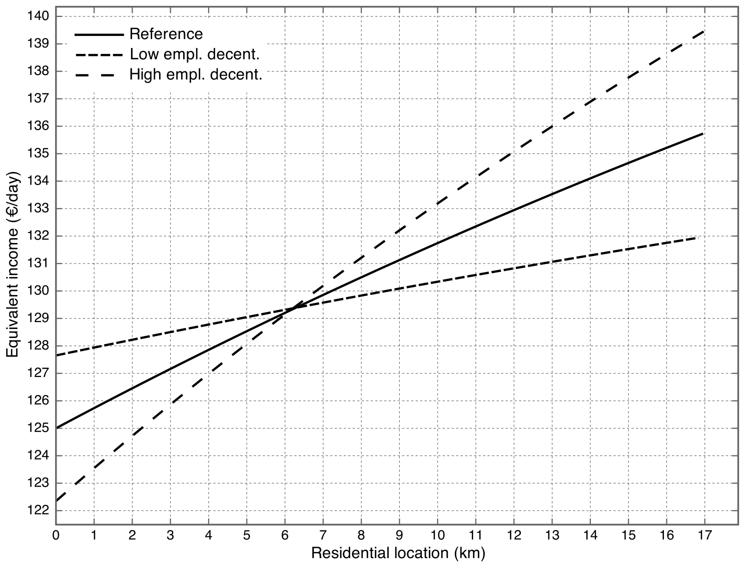

Figure 3: Equivalent income in the three scenarios.

5 Conclusion

This paper examined the impact of job decentralization on urban sprawl through a twofold analysis. First we found, with a theoretical framework based on the monocentric urban model, that job decentralization associated with transport congestion may yield a strong incentive to sprawl for households: households living far from the city center benefit from a low transportation cost to their workplace, while the distance they travel is long, entailing energy consumption, GES and pollution emissions.

Second, through a comparison of three scenarios, we found that, other things being equal, a more centralized employment area leads to a moderately smaller city, the elasticity of the city radius with respect to employment area radius being 0.01, but a large variation in the distance traveled, the elasticity being -0.4. This suggests, along with authors such that Melia et al. (2011), that urban intensification is hardly able to reduce land consumption but may on the contrary induce long traveled distances for home-to-work trips.

Finally, within this theoretical framework, our findings qualify the widely held view that the compact city is the most efficient urban form. Our results suggest that a city where employment is partly decentralized may be efficient in terms of transport, without excessive land consumption.

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